DSRC Roadside Unit "INFOBEACON" and Solutions Utilizing ETC On-Board Units

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Abstract

The ETC (Electronic Toll Collection) system is widely employed for collecting road tolls. The vehicle ID service of the ETC has recently been made public in order to promote the multipurpose uses of ETC on-board units in applications other than for the toll collection. This has aroused a need for low-cost DSRC (Dedicated Short Range Communication) roadside units among the service providers, who plan to develop services that utilize vehicle IDs. NEC has recently been developing the INFOBEACON in order to meet this need. This paper describes the background of development and features of the INFOBEACON together with examples of its applications, such as a vehicle management system and an actual case of a pilot program.

Keywords

DSRC, ETC, ETC on-board unit, vehicle ID, roadside unit, multipurpose uses

1. Introduction

ETC (Electronic Toll Collection) is a system for collecting road tolls via DSRC (Dedicated Short Range Communication) wireless communication when vehicles pass through the tollgates without stopping. ETC has spread rapidly in Japan since the beginning of its public operation in 2001 and by November 2007 the accumulated total number of ETC on-board units exceeded 20 million units. At present, about 70% of vehicles using Japanese expressways install ETC on-board units.

In March 2006, the Japanese Ministry of Land, Infrastructures and Transport and the Organization for Road System Enhancement (ORSE) initiated the vehicle ID service of ETC so that ETC on-board units that had previously been used only for toll payments could be applied to multipurpose uses by private businesses, etc.

2. The Vehicle ID Service and Its Examples

The vehicle ID is information that corresponds to device ID that is one of the pieces of information unique to each ETC on-board unit. A service provider introducing the vehicle ID service can identify ETC on-board units from vehicle ID and provide more detailed services for each user according to each vehicle.

Examples of services applying the vehicle IDs include; 1) vehicle entrance/exit management at monthly rented parking lots, apartment houses or factories; 2) CRM (Customer Relationship Management) services including guest arrival notifications connected with the entrance/exit of vehicles and the distribution of advertising e-mails; 3) payment settlement services in pay-by-the-hour parking lots, gas stations and drive-through shops etc. Please note that payments using the vehicle IDs are based on a mechanism that is different from the ETC toll payment of toll roads and requires advance registration of the information on the credit card to be used.

3. Development of INFOBEACON

As the ETC roadside units were initially very expensive, the service providers needed to introduce DSRC roadside units that are less expensive and easier to install. The INFOBEACON was developed in order to meet this requirement (**Photo 1** , **Table**).

In the following sections, we will discuss issues related to the development of the INFOBEACON, the solutions adopted to deal with them and provide a summary of an experiment that was made in an equivalent environment to a gas station.

3.1 Development Issues and Their Solutions

The main issues in the development of the INFOBEACON

were "reduction of equipment cost" and "improvement of ease of installation and reduction of installation cost." Specifically, these issues were solved as described, before the INFOBEACON product was commercialized.

1) Reduction of Equipment Cost

With ETC, the toll for road use is settled at tollgates using an ETC card. The information in the ETC card is encrypted with SAM (Secure Application Module) and transmitted between the ETC on-board units and roadside units. SAM is expensive and consequently vehicle ID services are not currently able to utilize ETC card settlement with SAM.

In addition, with the ETC roadside units, the radio wave irradiation area is defined strictly in order to prevent radio wave leakage to adjacent lanes, their antennas are large and expensive, and the antenna and the control units are separated.

With INFOBEACON, we omitted SAM unnecessary and restricted the beacon function to the acquisition of the device ID, which is unique information to each ETC on-board unit and the WCN (Wireless Call Number). This strategy has made it possible for us to review the antenna, circuitry and parts, integrate the antenna and control units, and thereby to reduce the cost of the equipment.

2) Improvement in the Ease of Installation and Reduction of Installation Costs

Various places are designed for the multipurpose uses of ETC on-board units, including such facilities as gas stations and parking lots. In these applications, roadside units should be installed in the proximity of the dispenser in the case of a gas station (**Photo 2**) or in the proximity of the ticketing and payment machine at the entrance and exit in the case of a pay-by-the-hour parking lot. However, these locations do not always have adequate space for installing additional equipment. If the antenna and control units are separated, it might be difficult to install the control unit in such a place and the installation cost would consequently be increased. Additionally, work would also be required for supplying power to the antenna and the control units.

In order to deal with the above issues, we have designed INFOBEACON by integrating the antenna and the control units for ease of installation and have given them a compact volume of about 1/30th of that of our previous roadside units. In

Photo 1 INFOBEACON (with bracket).

Table Specifications of INFOBEACON.

Item	Specifications
Technical standard	ARIB STD-T75
Radio characteristics	
TX frequencies	5,795MHz, 5,805MHz
RX frequencies	5,835MHz, 5,845MHz
Modulation	ASK modulation
Transmission rate	1,024kbps
Dimensions & weight	
Dimensions	182W × 188H × 115D mm (exclud. Bracket)
Weight	Approx. 1.2kg (exclud. Bracket)
Environmental characteristics	
Operating temperatures	-10 to +50°C
Protection class	IP55 equivalent
Interfaces	
Physical interface	100BASE-TX
Communication protocol	TCP/IP Socket
Power supply	Power over Ethernet (IEEE802.3af compliant)

Photo 2 Image of an installation at a gas station.

addition, we have adopted the PoE (Power over Ethernet) that is standardized as IEEE802.3af as the means of power supply. This makes it possible to supply power to the INFOBEACON with a LAN cable from a PoE-compatible hub, and makes power installation work at the installation site unnecessary. With the integration of the antenna and control units, reduction of the equipment volume and use of PoE, we have succeeded in improving the ease of installation at the same time as reducing the installation cost.

3.2 Summary of INFOBEACON Performance Evaluation Experiments

Cashless payment of gas charges at gas stations is one of the promising services based on the multipurpose uses of vehicle IDs, but this necessitates a strictly accurate identification of the refueling vehicles. However, the gas station is one of the locations where the installation of roadside units is most difficult to achieve because it does not have strictly-fixed vehicle lanes. A different vehicle often passes very close alongside a refueling vehicle and there are radio wave reflection sources such as the dispenser. However, this issue tells us that, if we are able to use the service effectively in a gas station, we could introduce similar systems more easily in places where the entrance/exit lanes for vehicles are more strictly defined. Therefore, we conducted an experiment for evaluating the radio wave properties of INFOBEACON and the effects of radio wave reflections on it in an environment equivalent to a gas station.

The radio wave targets the position of the ETC on-board unit, but in actual installations, the positions of the antenna of the ETC on-board unit varies between vehicles. In addition, the vehicle stopping positions in gas stations are determined according to the positions of the filler opening on the vehicle and the petrol dispensing pumps. In this experiment, we set a radio wave target area of a certain size and adjusted the electric field strength so that the ETC on-board unit in the area can always respond to the radio wave. Some of the experimental results are given below.

1) Comparison of Simulation and the Actual Measured Results

We installed an antenna for an ETC on-board unit in each test vehicle and measured the strength of the radio wave received from the INFOBEACON while gradually moving the vehicle. The radio wave reflections and the multipath fading due to the dispenser had not been considered in previous simulations. However, we were able to confirm that the electric field strength that an ETC on-board unit complying with the standard received was almost coincident between the simulation and the actual measured results of the experiment.

Photo 3 View of experiment.

2) Influence of Adjacent Vehicles

In a gas station vehicles other than the target vehicle frequently pass by or stop nearby. This means that there is a possibility of charging incorrect vehicle for the refueling if communication with another vehicle happens by mistake. Therefore, we performed an experiment to judge whether the ETC on-board unit of the adjacent vehicle is communicating with INFOBEACON, when another vehicle stopped nearby the refueling vehicle (**Photo 3**).

As a result, we confirmed that the ETC on-board units of the non-target vehicles do not communicate with the roadside unit, even when it is located closely to the target vehicle.

The above experimental results have shown that the possibility of incorrect communication is able to be considerably reduced if INFOBEACON is installed properly. In actual introductions, it is important to install INFOBEACON in optimum positions that match the installation environment.

4. Vehicle Management System Using the INFOBEACON

4.1 Outline of the Vehicle Management System

Another service that may conceivably benefit from the use of ETC on-board units and INFOBEACONs is a "vehicle management system," for controlling the entrance and exit of

vehicles that have been registered in advance. When installed in a monthly rental parking lot or parking facilities of apartment blocks or factories, the system is expected to influence the following; 1) automatic and rapid processing of the entry/exit of registered vehicles; 2) improved security by preventing the trespassing of non-registered vehicles; 3) archiving of electronic data on the history of entry/exit; 4) improvement of entry/exit efficiency.

The vehicle management system is operated in the following series of steps (**Fig.**); 1) advance registration of the information on the vehicles permitted to enter, including datas corresponding to the vehicle (license plate number, etc.) and ETC on-board unit data (vehicle ID or WCN); 2) when a vehicle enters the factory or parking lot, the INFOBEACON at the entrance communicates with the ETC on-board unit to identify whether or not it is a registered vehicle; 3) when it is a registered vehicle, the system opens the entrance gate; 4) the vehicle enters the parking lot and parks in the specified position; 5) after works such as unloading/loading cargo, the vehicle moves to the exit; 6) the INFOBEACON at the exit communicates with the ETC on-board unit and identifies the exiting vehicle, and the system opens the exit gate.

4.2 Example of an Actual Introduction

We introduced the INFOBEACON in the pilot program of a "Shared Parking Lot for Delivery Vehicles Utilizing ETC On-board Unit and DSRC" being held in Toyota City, Aichi, which is an ITS advanced area in Japan. In this experiment, a space dedicated to delivery vehicles was prepared in a pay-by-the-hour parking lot. When a previously registered delivery vehicle enters the parking lot, the entrance gate is opened, and the obstructive flapper blocking the entrance of ordinary vehicles into the dedicated area opens so that the vehicle can park in the dedicated space for handling the cargo. In this experiment, NEC and NEC Engineering installed INFOBEACONs for use in identifying the ETC on-board units of registered vehicles, based on the vehicle IDs. They also had to adjust the devices in the field and to build a system for transmitting the information collected with the INFOBEACON to the parking lot management equipment (**Photo 4**).

A summary of the pilot program is as the following.

(1) Purpose

Measurement of the effectiveness of the "parking model," including activation of the central urban area, improvement of the environment (CO_2 reduction) and countermeasures against traffic congestion due to accidents.

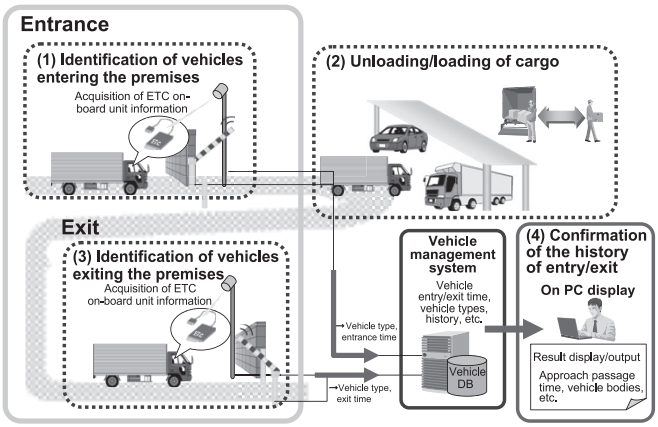

Fig. Image of vehicle management system operation.

Photo 4 View of pilot program.

(2) Place

Parking lot at the Nishi-machi shopping area, Toyota City, Aichi, Japan.

(3) Targets

Logistics business companies and their delivery vehicles that are registered to perform cargo-handling work in Toyota City.

(4) Organization

Organizer: Toyota Municipality, Aichi, Japan.

Experiment model study: Subcommittee on ITS Business Development, Committee on Civil Engineering Information Processing, Japan Society of Civil Engineers (JSCE).

Administration: Highway Industry Development Organization (HIDO)

System design/operation: Parking & Transportation Engineering Company (P&TEC)

Builders of INFOBEACON utilization system: NEC Corporation, NEC Engineering, Ltd.

(5) Term

August 2007 to End March 2008 (still under experiment when the present report was written)

(6) Outline of Cargo Handling Depot System

1) The logistic business registers in advance the vehicle IDs of the freight vehicles mounting the ETC on-board units.
2) The driver makes reservation for use of the shared parking lot via cellular phone, etc.
3) When the reserved vehicle arrives at the entrance of the parking lot, the gate opens automatically so that the vehicle can enter the parking area without receiving a parking ticket.
4) The flapper of the dedicated space drops so that the vehicle can park and perform the cargo-handling work.
5) After the work is completed and the vehicle approaches the exit, the gate opens automatically so that the vehicle can exit the parking area without having to settle a parking fee.
6) The parking fee is totaled and billed to the logistic business at the end of each month. The fee can be finely calculated in 1-minute steps.

The full results of this pilot program have not been compiled yet because it is still underway as this paper is written. However, it is expected to contribute to a reduction in urban traffic-related problems including the prevention of accidents caused by vehicles that repeatedly park illegally for delivery packages handling. It will also help prevent global warming by contributing to a reduction in CO_2 emissions.

5. Conclusion

As described in the above, the INFOBEACON makes it possible for service providers to introduce it easily by reduction of the equipment and installation costs, and improvements in the ease of installation. Applications of the INFOBEACON are proposed for multipurpose uses of ETC on-board units at gas stations, parking lots, etc.

Although there are still few actual examples of multipurpose uses of ETC on-board units because the system has not been permitted for a long time, the INFOBEACON is however expected to increase examples of multipurpose uses and to contribute to further dissemination of ETC on-board units.

References

1) Association of Road Industries and Businesses: "ARIB STD T-75 Ver. 1.3, Dedicated Short-Range Communication System," 2005.
2) Association of Road Industries and Businesses: "ARIB TR-T16 Ver.1.3, Dedicated Short-Range Communication System Test Items and Conditions for Mobile Station Compatibility Confirmation," 2005.
3) Organization for Road System Enhancement (ORSE) website: http://www.orse.or.jp/
4) Introduction of User Vehicle ID Service: http://www.orse.or.jp/division/service01.html
5) Ministry of Land, Infrastructures and Transport: ITS website, http://www.mlit.go.jp/road/ITS/j-html/
6) Highway Industry Development Organization (HIDO) website: http://www.hido.or.jp/

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